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THE PREVENTION OF INFESTATIONS OF INSECTS AND OTHER PESTS  
IN COMMERCIAL MUSHROOM HOUSES

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Control of mushroom insects, once they are established in the houses, is very difficult, owing to the extreme sensitiveness of the mushrooms to chemicals and because the chemicals that are safe to use do not penetrate into the beds readily. For this reason it is desirable to prevent the initial infestation by freeing the house and compost of pests before spawning, and to prevent the pests from entering the house thereafter. The following suggestions will, if carefully followed, assist materially in preventing infestation.

## Composting

Upon receipt, the manure should be well forked over, all lumps and cakes broken up, and straw added if necessary. The temperatures within the heap, except at the ground level, are too high to allow insects to survive, but they can develop in the cooler outside portion of from 3 to 6 inches. The heap should therefore be kept well ricked up during the composting so as to expose as little surface as possible to insect attack. Along the ground level the temperatures are much lower, often under 100° F. It has been found that in the lower third or more of the compost heap the amount of oxygen diminishes and the carbon dioxide concentration rapidly increases to the point where no further fermentation takes place; i.e., the manure in that part remains "green" until it is thrown to the outside at the next turning. This combination of low oxygen and high carbon dioxide concentration, while perhaps causing insects to become inactive, probably kills few of them and does not prevent the entrance of others from the outside. It is possible to induce more uniform composting and destroy more of the insect life by ventilating the lower part of the heap by laying bench tile, drainage tile, or lattice frames beneath the heaps. The best is probably the lattice frame, consisting of several inverted "U" or "V" ribs with 1 x 2 inch boards nailed along them about an inch apart. Ventilation beneath the heap admits oxygen, and this allows the manure in the lower third of the heap to compost and thus raises the temperature to the point where insects and mites cannot survive. Since the circulation of air also allows moisture to be carried off, extreme care must be used so that the heap does not dry out excessively.

Composting is best done upon a concrete floor. This prevents the entrance into the manure of many pests from the ground, and, if there is a gutter around the edge that may be kept filled with water, many fly maggots will be trapped and drowned therein as they leave the manure. Lacking such a floor, the ground upon which the compost heap is to be placed should be well



smoothed and cleaned, then thoroughly drenched with a solution of 1 pint of fresh formaldehyde to 15 gallons of water. A couple of days should be allowed for this to disappear before the manure is unloaded.

### Preparation of the House

Before being filled the house should be sprayed with lime-sulphur or fumigated with either formaldehyde or sulphur. Formaldehyde is a good germicide and fungicide, but the gas from burning sulphur is almost as good and is also a powerful fumigant, especially against mites. Before the house is fumigated it should be made as airtight as possible by tightly closing all ventilators and other openings and by pasting paper or plastering mud over all cracks.

A good grade of flowers of sulphur should be used at the rate of 5 or 6 pounds per 1,000 cubic feet of air space. The most common method of burning it is in metal pans or trays with the edges high enough to prevent the molten sulphur from flowing and setting fire to the house. A little excelsior or crumpled paper is placed along the bottom of each of 4 or 5 pans and the sulphur poured along each side of it. Some growers prefer to use less sulphur per pan, covering the bottom of each tray with about an inch of excelsior and sifting the sulphur over this. Still another method is to put excelsior in the bottom of the container and over this place a piece of coarse screen, cover the screen with a piece of newspaper, and pour the sulphur upon this. The use of a larger pan containing water, into which the smaller one containing the sulphur is placed, is a great aid in preventing fire and accidents. In the case of houses having dirt floors, pits may be dug therein and the sulphur burned as in the pans. Sulphur should not be burned upon concrete floors, as the heat is likely to cause the concrete to crack and buckle, throwing the burning sulphur about and setting fire to the house. In any method the important thing is to get a complete combustion in as short a time as possible. Recent experiments have shown that it is almost impossible to get a complete combustion by any method of burning sulphur within the houses, and that the time required for burning averages about 3 hours.

An apparatus that burns sulphur outside the house and forces the fumes in by means of a centrifugal fan has been used with great success for fumigating mushroom houses. This consists of a tight galvanized metal box provided with 3 pans arranged one above the other for burning the sulphur, and with baffles so arranged that the air from the fan is distributed evenly over all the pans. The burner produces a highly concentrated gas in the houses with less than a third the amount of sulphur required by the pan method, and burns the sulphur completely in about 30 minutes. Most of the fire hazard is avoided by its use.

### Filling the House

When compost is placed in the beds a secondary fermentation takes place and the temperature starts to rise. A small quantity of manure in a large cool place will not heat up so well as a greater quantity, nor will it raise the temperature of the surrounding space greatly. If the filling occupies too much time considerable heat is wasted. For this reason the house should be filled as quickly as possible, the aisles swept out and cleaned of all loose



manure, and the doors closed tightly. Some growers fill a part of the house and wait for several days before filling the remainder. If manure is scarce, it is better to form storage heaps until enough is obtained to fill the house in one operation.

It is most important that a good heat be obtained at the time of filling, because heat is the mushroom growers' easiest, cheapest, and best method of combating insect pests, as well as being necessary to "sweat out" the manure and put it in the best condition for the spawn to run. An ideal condition is to have the bottom beds above 120° F. and the top beds below 140° F. At these temperatures all insect life will either be killed or driven to the surface of the beds, where it can be reached with fumigants. Ground beds are very difficult to heat properly. The insects will not be driven to the surface, and, since the fumigants in use at present do not penetrate the compost more than an inch or so, these pests will survive and reinfest the house. If the ground beds cannot be raised 4 or 6 inches from the floor to allow circulation of heated air beneath, then it is better to abandon them entirely. The temperature of the bottom beds will lag about 10 degrees behind that of the top ones, and the air temperature will usually be 15 or 20 degrees less on the floor than under the ceiling.

If the weather is very cool at the time of filling, the house may be heated. Where steam or hot-water heat is not available, kerosene or oil burners have been used with success. Care must be used that the beds do not dry out too much while this is being done.

Because the lower beds are filled first and lose much of their latent heat, and also because the warm air naturally rises to the top of the house, the top beds heat faster and attain a higher temperature than the bottom ones. A more even distribution of heat may be secured by the use of some method of forced air circulation. Where electric current is available the best method is to place 2 or 3 16-inch electric fans in the central alleyway, so adjusted that the air current is directed upward at an angle of from 45 to 80 degrees along the center of the house. When the top beds have reached a temperature of 120° to 130° F. the fans should be started, run for 5 or 6 hours, shut off to cool for 2 or 3 hours, and then run for another 5 or 6 hours.

To keep check upon the conditions during the heating, accurate thermometers should be inserted into the top and bottom beds and hung in the central alleyway at the top and bottom of the house. In no case should the temperature of the beds be allowed to go above 145° F.

#### Fumigation

When the temperature of the beds has reached its maximum, the house should be fumigated with either sulphur or cyanide.



Sulphur. - Sulphur should be burned at the rate of  $1\frac{1}{2}$  to 2 pounds per 1,000 cubic feet of air space. Do not use more than 2 pounds per 1,000 cubic feet. Within 5 or 6 hours after the sulphur has finished burning the ventilators should be opened, the house allowed to air out, and then closed again to prevent too rapid cooling. Owing to the slow rate of burning and the rapid absorption of gas by the moisture in the house, it is doubtful if an efficient fumigation is ever secured by burning sulphur in pans within the house at peak heat. The outside burner referred to above will give much better results.

Sulphur fumigation has a tendency to raise the acidity of the first one-half inch or so of the beds (the limit of penetration of the gas) and a green mold often follows. This soon disappears, however, and neither it nor the increased acidity of the surface of the beds seems to have any harmful effect upon subsequent mushroom growth.

When a house to be fumigated is immediately adjacent to another in production, every precaution should be taken that the fumes do not reach and damage the growing mushrooms. The ventilators of the house in bearing should be open, and the house in heat should be fumigated only when there is no wind, or when the wind is blowing away from the house in bearing. In case of a double house, the other half of which is in bearing or spawned, it is better to use cyanide rather than to risk damage from sulphur fumes.

Calcium cyanide. - The use of calcium cyanide at the rate of 1 pound per 1,000 cubic feet of air space is at present the most common method of fumigating mushroom houses at peak heat. As hydrocyanic acid gas is readily absorbed by moisture, the house, although damp, should not be wet, with puddles of water standing in the alleyways, or much of the gas will be lost before it is fairly liberated. Experiments have shown that the maximum concentration of gas is reached in 10 to 20 minutes after the cyanide is scattered. In view of the deadly nature and the rapid evolution of this gas, every precaution should be used against accidents. In the case of a single house the chemical should be scattered in the central alleyway as evenly and quickly as possible, beginning at the back of the house and working toward the door. Be sure that the alleyway is clear of obstructions before starting, as a stumble over some obstacle while walking backward and scattering the cyanide might easily result fatally. In case of a double house the material is scattered in the two main alleyways, the workers starting together at the far end and working toward the doors, timing themselves so as to reach the doors simultaneously. After the operators have left the house the doors should be closed and tightly sealed, and left so for about 12 hours. Experiments have shown that the gas is taken up so rapidly by the moisture that it is safe to enter some houses as soon as 3 hours after fumigation, but with so deadly a gas a generous margin of safety is advisable. The same precautions are necessary as with sulphur to prevent fumes from reaching and damaging growing mushrooms, although this gas is not so harmful to them as sulphur fumes. In case of a double house the other half of which is in bearing, the doors between them should be made gastight, all cracks and openings in the partition tightly sealed, and the doors and ventilators of the house in bearing opened. It is better to fumigate when the wind is blowing away from the house in bearing.



Sodium cyanide. - The so-called pot method of cyanide fumigation is almost as easy and convenient as that with calcium cyanide, gives a more rapid liberation of gas and a much higher concentration, and is about half as expensive. With sodium cyanide it is possible to set off a second charge from outside the house, should this be necessary, after 15 or 20 minutes, when the concentration of gas from the first charge has become rather low, thus practically doubling the time of exposure of the pests to the gas and increasing the probability that every crack and crevice of the house has been reached.

The material should be used at the rate of not less than 8 ounces of sodium cyanide to 12 fluid ounces of a good grade (66° Beaume) of commercial sulphuric acid and 16 fluid ounces of water per 1,000 cubic feet of air space. Three or four 3-gallon glazed crocks may be used for generators. The necessary amount of water is measured out and divided among these. They are then set at equal intervals in the central alleyway of the house. The acid is similarly measured out and the necessary amount placed in a glass jar beside each generator. The sodium cyanide having been similarly weighed out (it can be secured in  $\frac{1}{2}$ -ounce or 1-ounce "eggs" to save this work), and the proper amount for each jar having been put into a heavy brown paper bag (the thickness of paper may be doubled for additional safety by using two bags, one inside the other, for each charge), the operator takes the twisted necks of the bags in his left hand, enters the house, and pours the acid into each generator as he reaches it. Having reached the back of the house, he then walks rapidly toward the door, placing one of the bags of cyanide in each generator as he passes it. The acid requires a short time to eat through the paper bags, and the operator is usually well outside the door before the first charge commences to generate.

The floor is always the coolest part of the house, and it is here that insects and mites are most likely to survive the heat. It is therefore desirable that as much of the gas as possible be kept in the lower part of the house. Unless fans are kept running in the house at the time of fumigation, the gas, being hot as well as lighter than air, will rise to the top of the house. The best results have been obtained by raising the fans to the level of the fourth or fifth beds, about 5 to 6 feet or more from the floor, with the air directed straight down over each generator. This causes the gas to blow along the floor between the lower beds. After 20 or 25 minutes the concentration becomes nearly uniform throughout the house, but for the first 20 minutes most of the gas is along the floor where it is most needed.

There are several methods of setting off successive charges. The simplest one is to have two sets of jars or generators, one set previously prepared with the cyanide in bags suspended over each generator from strings which lead out of the house through a small hole in the door. These strings may be released from outside the house at the proper time, dropping the cyanide into the second set of jars.



Sodium cyanide is extremely poisonous, and great care should be exercised in handling it. It should be stored under lock and key where it is not accessible to children or careless persons. The same applies to the acid.

### Sanitation

After the house has been through the heat and properly fumigated, precaution should be taken to prevent reinfestation by insect pests. Doors and ventilators may be made flytight with cheesecloth or, better, 30-mesh copper screen, if it is found possible to do so without interfering too much with ventilation. This prevents the entrance of flies and also of any mushroom mites that they may be carrying.

In passing from a house infested with mushroom pests to one not so infested, great care should be taken that no insects are carried on the person or clothing.

All stem-butts and discarded mushrooms should be carried away and burned, or placed in a hole, then covered with quicklime or kerosene and a layer of earth. They should never be allowed to stand about the house.

When the house has finished bearing and is about to be cleaned out, it should be allowed to dry out thoroughly and be fumigated if possible. In any case, the spent compost should be hauled to some distance from the houses and spread out thinly over the soil so that the weather may destroy as many of the pests as possible.

### Temperature

The temperature of producing houses should be held as nearly as possible around 55° F. This seems to be the temperature most favorable to mushroom growth and is cool enough to retard materially the development of pests.

### Control in Bearing Houses

The purpose of the treatments and practices recommended in the preceding sections is to prevent the infestation of beds. To date no entirely satisfactory methods have been devised for the control of insects in the beds, once these have been spawned. Most chemicals used for this purpose either do not penetrate the beds deeply enough or they have a harmful effect upon the spawn, which is very easily damaged. Destruction by heat prior to spawning and the prevention of reinfestation, as outlined under Preparation, Filling the House, and Sanitation, are the only successful methods known at present.

Both sciarid and phorid flies may be controlled to a great extent by destroying the adults, preventing oviposition, and thus cutting down the number of larvae in the beds. The house should be carefully watched, and as soon as a few flies appear it should be treated with a dust composed of 60 percent pyrethrum and 40 percent finely ground clay or diatomaceous earth (of which there are several kinds on the market) at the rate of 2 or 3 ounces per 1,000 cubic feet of air space. Most growers dust 2 or 3 times a week. The tempera-



ture of the house should be allowed to reach 60° F. or more, dusted, and left closed over night. At any lower temperature the flies are less active and the dust more inert. A good fan-type duster should be used and the dust thoroughly distributed throughout the house. Some growers have used commercial fly sprays and have claimed success with them; but since oil or oil fumes are destructive to mushrooms, such sprays should be used with caution.

Flytraps have been used with success, but they should be considered merely supplementary and not be depended upon to the exclusion of dusting. The simplest type of trap is a pane of glass set into the south or east end of the house, usually in the door, about a foot or more above the floor. Fly paper or sticky tree-banding material is placed about this to catch the flies as they come to the light, or a pan containing a little kerosene may be placed beneath it, into which the flies will fall and be killed. The pane of glass should not be too large, as the ends of the beds will then be too well illuminated and the female flies will often oviposit before they go to the glass, or will not be attracted at all. Electric lights, each over a pan of kerosene, are effective, especially in the upper part of the house. Traps in which a light is used to attract the flies and a fan to draw them in and hold them are also quite effective. One of this type, used experimentally in a very heavily infested house, caught over 187,000 flies in one 24-hour period, of which 75 percent were females and more than half of these had not yet laid all their eggs.

Calcium cyanide, at the rate of  $1\frac{1}{2}$  to 2 ounces per 1,000 cubic feet, has proven successful against adult flies if carefully used, but is said to retard the mushrooms if the fumigation is repeated too often or kept up too long. It is best to use it between "flushes". The beds should be allowed to dry out somewhat, all salable mushrooms picked off, the temperature allowed to rise to at least 60° F., and the house fumigated and left tightly closed for several hours.

A nicotine-lime dust containing 3 percent of free nicotine has been found to be quite effective against springtails upon the surface of the beds and on the floor, but does not penetrate into the beds. Paradichlorobenzene and several other insecticides are of some value, but further experimentation must be done before the conditions under which these may be safely used are fully understood, and their general use cannot be recommended.



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closed over night. At any lower temperature the flies are active and the  
next morning. A good fan-type heater should be used and the dust, if possible,  
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and have claimed success with them; but since all or old house fly preventive  
to maintain, such sprays should be used with caution.

Flies have been used with success, but they should be considered  
only supplementary and not be depended upon for the eradication of a fly.  
The simplest type of trap is a pane of glass put into the south or east wall  
of the house, usually in the door, about a foot or more above the floor. Fly  
paper or sticky free-hanging material is placed about 1/2 inch from the glass so  
they come to the light, or a pan containing a little kerosene may be placed  
beneath it, into which the flies will fall and be killed. The pane of glass  
should not be too large, as the ends of the body will then be too well fitted  
into the pane and the flies will often fly out before they get to the glass, or  
will not be attracted at all. Electric light, such as a pan of kerosene,  
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infested house, caught over 15,000 flies in one 24-hour period, of which  
75 percent were females and were about half of those had not yet laid  
their eggs.

Calculus cyanide, at the rate of 1/2 to 2 ounces per 1,000 cubic feet,  
has proven successful against adult flies if carefully used, but it is said to  
contain the nucleus of the fungus which is repeated and often on leafy top  
food. It is best to use it between "flashes". The beds should be allowed to  
dry out somewhat, all soluble manures given off, the temperature allowed to  
rise to at least 60° F., and the house flushed and left slightly opened for  
several hours.

A nicotine-line dust containing 2 percent of free nicotine has been found  
to be quite effective against both the surface of the body and on  
the floor, but does not penetrate into the body. It is recommended that  
at other insecticides are of some value, but further experimentation must be  
done before the conditions under which these may be safely used are fully  
understood, and their general use cannot be recommended.

It is also recommended that the house be kept as dry as possible, and  
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